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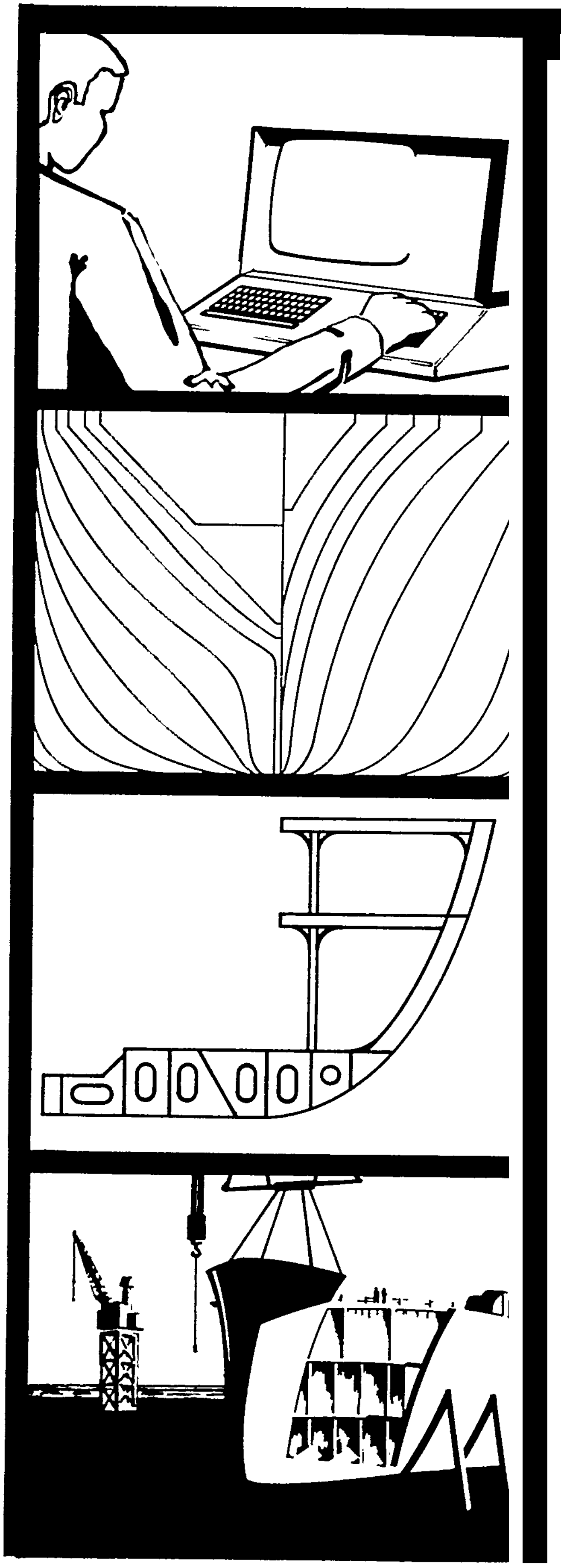

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IMPROVING LABOR PRODUCTIVITY IN SMALL SHIPYARDS WITH COMPUTER ASSISTED STRUCTURAL DETAILING

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IMPROVING LABOR PRODUCTIVITY IN SMALL SHIPYARDS WITH COMPUTER ASSISTED STRUCTURAL DETAILING

Introduction

This is a story of using small resources to solve big problems. It describes a system now in use involving an application of small computers in improving steelwork productivity in small shipyards. A notable feature of the system is that it requires almost no capital investment. The costs of the system are charged to the job and the learning time for using the system has proven to be very short. Labor savings are quite dramatic. Manhours per steelwork ton have been reduced as much as 50% in some cases. The major emphasis of the system is directed toward the improvement of the most important labor components of steelwork, fitting, welding and erection, rather than the steelwork areas normally cited as candidates for productivity improvement, layout and cutting. The system requires a few people with some skill in layout and planning but less shipbuilding knowledge on the part of the majority of the production labor force.

Hand labor is the most important component of shipbuilding and it is difficult to improve productivity by capital investment

Shipbuilding is a labor intensive business. For example, the cost of steel is only about 25% of the total cost of a ship hull. In addition to being the major cost, labor cost is more controllable by the builder than is almost any other cost. This is especially true for those shipyards who are not responsible for the design of the hulls they produce.

If labor costs are the major costs of shipbuilding and if they are more controllable by the builder than other costs, it follows that the greatest productivity improvements can be achieved by trying to reduce the amount of production labor.

There are two major types of work in a shipyard, steelwork and outfitting. Whether steelwork or outfitting has the most labor depends on the ship being built. Tankers, workboats, and barges have a higher steelwork labor content while Navy combatant ships have a much higher outfitting labor content.

In the steelwork area, the majority of manhours are in fitting, welding, and erection. Layout and cutting operations are only 10-15% of total steelwork manhours. In outfitting the most labor is in installation of outfitting items. Shop fabrication of outfitting items varies and is sometimes subcontracted but is invariably less labor intensive than installation.

Both major labor areas, steelwork, fitting, welding, erection and outfitting installation, are hand tasks and not very susceptible to automation or mechanization. Heavy capital investment in facilities is not likely to improve these major labor areas very much. This is borne out by Japanese experience. Some of the 70 year old Japanese yards are as productive as their brand new yards. The Japanese built their new yards to increase output or build larger hulls than could physically be produced in the older yards, not primarily to increase labor efficiency.

The major emphasis in this presentation will be on steelwork labor improvement since this is most important to builders of steel workboats.

Hand labor is more efficient if the worker understands his tasks clearly and his work is properly organized

If capital investment will not improve steelwork labor productivity, what will? The answer is twofold: (a) to improve the worker's understanding of his tasks by giving him clear work instructions and providing him with simple tools and, most importantly, all the material he needs to complete the work expected of him; and (b) scheduling the work so it is done earlier in the production process when access is better and work can be done most efficiently.

To illustrate the requirements for efficient fitting, welding, and erection let us consider the task of building a side shell panel for a steel hull. The following things are needed by the worker to do his job quickly and economically:

a) A picture of the completed panel showing what is installed on it and where it goes plus a list of what goes loose with the panel to the next assembly operation.

b) A list plus visual description of all the pieces he needs to make the panel plus where they come from in case they are missing.

c) Weld symbols, touch up paint, lifting lugs, scaffold clips, outfitting items to be installed, tasks to be done by other trades, etc.

d) Accurate dimensional information enabling work to be layed out, cut and assembled with minimum use of cut to fit procedures.

Shipyards often use Naval Architect's approval drawings for building. These drawings show the general construction but are poorly suited for direct use in the shipyard. The drawings are deficient in the following respects:

a) They are too big and show a little bit of information on a lot of hull. For example the Structural Profile shows a lot of structure all over the ship but not nearly enough to build a single panel.

b) Several large drawings are required to make one panel and a lot of study is required by the worker to figure out what he is supposed to do on his one panel.

c) Very little if any accurate layout information is included on any of the drawings.

d) There is no definition of what constitutes a completed panel or unit of work.

Under normal conditions a tremendous amount of production labor is spent on interpreting drawings just to figure out what to do. This is wasted time. The manager wants to see sparks and arcs, not people studying plans and looking for material.

The conclusion that must be drawn is that steelwork labor efficiency can be improved by giving the worker decent drawings and work instructions tailored to his tasks.

Production drawings prepared with computer assistance are necessary to achieve low steelwork manhours

Several small steel hulls have been built using special steelwork production drawings made with the aid of a minicomputer. This has been a small resource effort to solve a big problem. The computer does not make the drawings. It only provides lots of accurate dimensional information for use in making the drawings. To date the drawings are 100% hand made since we have been unable to justify a plotter for our computer.

The drawings themselves are made strictly for production purposes. A typical drawing will show an individual panel to be fabricated plus complete dimensional information and accurate bill of material. The mechanic needs only the one drawing to build the panel. The same drawing is used by the layout man to prepare the parts for use in building the panel. Using drawings of this nature, steel hulls have been built from prefabricated panels with less than 5% of seams trimmed at erection and then only an occasional sliver needs to be removed.

Using the production drawings the construction procedure is different from the normal small boat production procedure of laying the keel, erecting and guying off frames and bulkheads, installing longitudinals, and erecting, trimming, and fitting raw plate to the skeleton. The procedure with the production drawings is to fabricate and weld the panels on the ground, erect the keel and bulkheads, and erect the panels on the hull. Using the revised procedure about half the work normally done in the air is done on the ground where it is much easier to do and the remaining work done on the ship is reduced because trimming to fit is substantially eliminated. An additional benefit is that product quality is improved since weld gaps are just right and fitting panels rather than frames and plates gives a smoother hull. Less extra stiffening and trimming to fair up frames is necessary also.

Returned cost figures indicate that labor manhours, excluding the manhours spent in making the drawings, have been reduced by as much as 50% over conventional small boat building practice.

The type of production drawing used to achieve these savings requires accurate dimensional information from computer lofting and shell development to make the system work. Our concept is to use the computer as a tool to improve the essential hand labor tasks involved in steelwork. The production worker need not know anything about computers. He may not even see a computer printout or can be unaware that computers are helping him.

The drawings and work instructions he uses are tailored to the worker's needs, not to the requirements of the computer. The computer is subservient to the worker, not the worker to the computer system. This is very logical since there are a lot more workers than computers and computers operate at 60 HZ all the time while worker's output depends on how easy the work is, how they feel, etc.

Low steelwork manhours require labor specialization, repetitive tasks, and efficient positioning of the work. These are achieved with steelwork <u>production drawings</u>

Efficient utilization of labor involves a number of work organization features as follows:

a) Work tasks must be simply and clearly defined and done in a uniform way from job to job to reduce mistakes, slack time, and relearning.

b) Identical types of work must be lumped together so that batches of similar tasks are done at one time. For example, the ideal method of cutting parts is to light the burning torch once, and cut <u>all</u> the parts for an assembly before turning it off. This provides work task specialization, one of the most powerful ways of increasing productivity.

c) Work must be positioned properly for ease in doing the work. Consider fitting plating to frames. Fitting loose frames to plating on the ground in flat position under cover is more than three times as efficient as fitting plates to frames erected on the ship, especially if the plates and frames are cut properly in the first place.

d) Elimination of cut and try fitting operations saves both fitup labor and welding labor. Cutting plating to fit on the ship is very awkward. It requires a lot of out-of-position work plus extra equipment and scaffolding and the result is often pretty sloppy and requires extra welding time to fill up the gap. In contrast, fitting a properly cut seam together on the ship is quite simple if started in the right place and the weld seam quality is very good.

e) Erecting complete panels on the ship is cheaper than erecting frames, guying them off, aligning them and pulling raw plate to the frames since fewer pieces need to be erected and less supports used to keep everything in alignment.

From the above list it can be seen that there are substantial production economies to be obtained by changing the production process to take advantage of steelwork production drawings. The change in the production process is not a drastic one. The individual work tasks of layout, cutting, fitting, welding, and erection are still done the same way as always. They are only simplified and consolidated into repetitive batches to make it easier and more enjoyable for the worker.

The prefabricated panels are only 10% to 20% heavier as a rule than an untrimmed plate so required crane capacity is little different than before.

Are 50% steelwork labor savings unrealistic? Surely yes for a fairly efficient yard already building panels but not for a yard using conventional cut and try methods and doing most of the work on the ship.

Some justifications for the 50% level of potential savings are:

a) Fitting and welding stiffeners to plates on the ground requires one third the manhours of doing the same thing in the air on the ship.

b) Fitting and welding plate seams which need not be trimmed is less than half the cost of trimming, fitting and welding raw plate.

c) Batch processing in layout, cutting and panel assembly is less than half the labor cost of cut and try methods.

d) Standby time and study time by workmen is cut about in half.

e) Accurate Bills of Material eliminate lost time hunting for material.

f) When the draftsman makes the drawings, he simulates the layout and assembly process that the production worker uses. In doing so he uncovers problem areas and makes "mistakes" on paper which he can correct as he goes along. It is far cheaper to make mistakes on paper and correct them than on steel. While not infallible, the detailing process does result in fewer errors and less rework than "leaving it up to the boys on the ship."

Each of the above savings is substantial, many more than half of conventional labor requirements. From this cursory analysis labor savings of 50% over conventional small yard fabrication methods are not unreasonable. At any rate the labor savings will far outweigh the cost of preparing steelwork production drawings.

Typical Steelwork Production Drawings contain a wealth of information for the worker and promote efficient planning

Steelwork Production Drawings are product oriented not systems oriented, local in scope not global, and complete in their local area. They contain the following:

a) A picture of the work to be done giving all necessary layout information either in tabular form or by dimensions on the part.

b) Accurate Bill of Material enabling raw material to be consolidated before fabrication is started.

c) Source and destination references for material

d) Forming instructions for parts requiring forming.

Some special features of the format are worth mentioning:

a) Each drawing covers a clearly defined series of tasks and is generally independent of other drawings.

b) Each drawing is essentially preplanned so that production planning instructions over and above those incorporated on the drawing are minimal. The planner need only say "do it by X date" to complete the work authorization.

c) Having layout dimensions on the drawings simplifies checking of work and improves the fabrication accuracy thereby lowering the cost.

d) Drawings are fairly small and easy to handle on the job. If there are problems, say a piece is missing, there is a clear picture of the piece somewhere on the drawing. A journeyman can send a helper to look for it rather than have to go himself.

Steelwork Production Drawings are probably more expensive to prepare than normal working drawings. It is usually not necessary to prepare both working drawings and steelwork production drawings. Starting from the approval drawings submitted to Coast Guard or ABS, the Steelwork Production Drawings can be prepared directly. Preparation costs depend on a lot of factors. A typical cost for 1/4" plate with 18" frame spacing for a high class workboat is about $150.00 per ton. For 1/2" plate this cost could be reduced about 40%.

A comment is in order on layout accuracy. Many authorities state that Numerical Control is required for super accuracy in cut parts. The reason for super accuracy is not Numerical Control; it comes

mainly from the computer. For example, if a shell plate were developed by hand, digitized, and cut by Numerical Control it would not fit too well because the errors in hand development are accurately incorporated into the cut plate according to the garbage in-garbage out principle. If a shell plate is computer developed, layed out by hand and cut by radiograph, the fitup will be excellent. The accuracy comes mainly from the computer, not from the N/C machine.

Steelwork Production Drawings are dependent on accurate dimensional information which can only be generated by computer. The computer need not be large to do the job. A minicomputer can develop shell accurately and also come up with accurate returned offsets. This is all that is needed to prepare accurate Steelwork drawings and achieve really substantial savings in fitting, welding, and erection labor.

No capital investment is required to achieve these savings; the costs of making the computer runs and drawings are charged to the job and are paid for by production labor savings.

Actual work experience with computer assisted Steelwork Production Drawings has been very profitable to builders using them.

Steelwork Production Drawings have led to notable production savings in small yards. Some examples follow:

A Central American shipyard built two 72 foot Shrimpers using Steelwork Production Drawings. They were the first steel hulls ever built in the yard. The yard manager, an American, said that he would have had to go out of business without the drawings. He is planning to use them on a pending order for ten anchovy boats.

A small builder used Steelwork Production Drawings on the forward half of an 80 foot hull. The after part was built conventionally. The construction manhours were half as great

for the forward part than they were for the after part. The shipyard personnel commented on how easy it was to install the prefabricated panels compared to erecting frames and pulling plate to the frames. They also stated they were able to do more and better work with far less effort.

A small repair yard is presently building their first steel hull, a 50 foot water taxi. Because of the detailing and planning contained on the Steelwork Production Drawings, they ordered domestic steel from the mill rather than from the warehouse and saved about 10% from the foreign steel price. They have worked an average of two men per day for 3 weeks straight time only and have completed almost half of the panels ready for erection including blasting and priming of the steel. This includes setting up a work area from scratch and training yard personnel with no previous steel hull building experience. This job is still underway and yard personnel are eager to work on the job. The work pace is very good because the work is clearly laid out on the drawings and there is always something ready for doing. Just pick up a drawing and go to work!

Every user of Steelwork Production Drawings is convinced of their utility in increasing labor productivity, improving quality of the work and making the work easier to manage. They are all going to use the system on their future jobs.

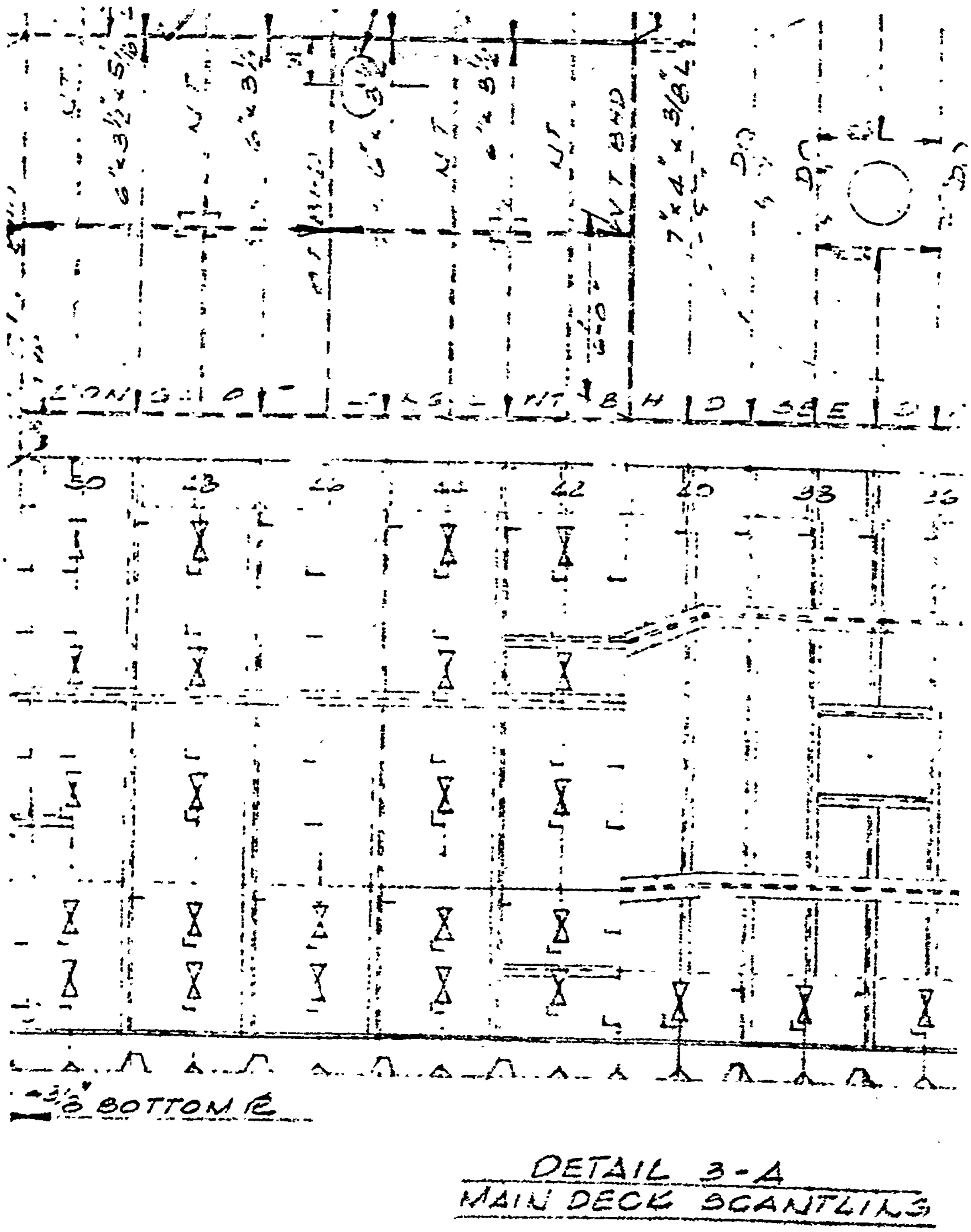
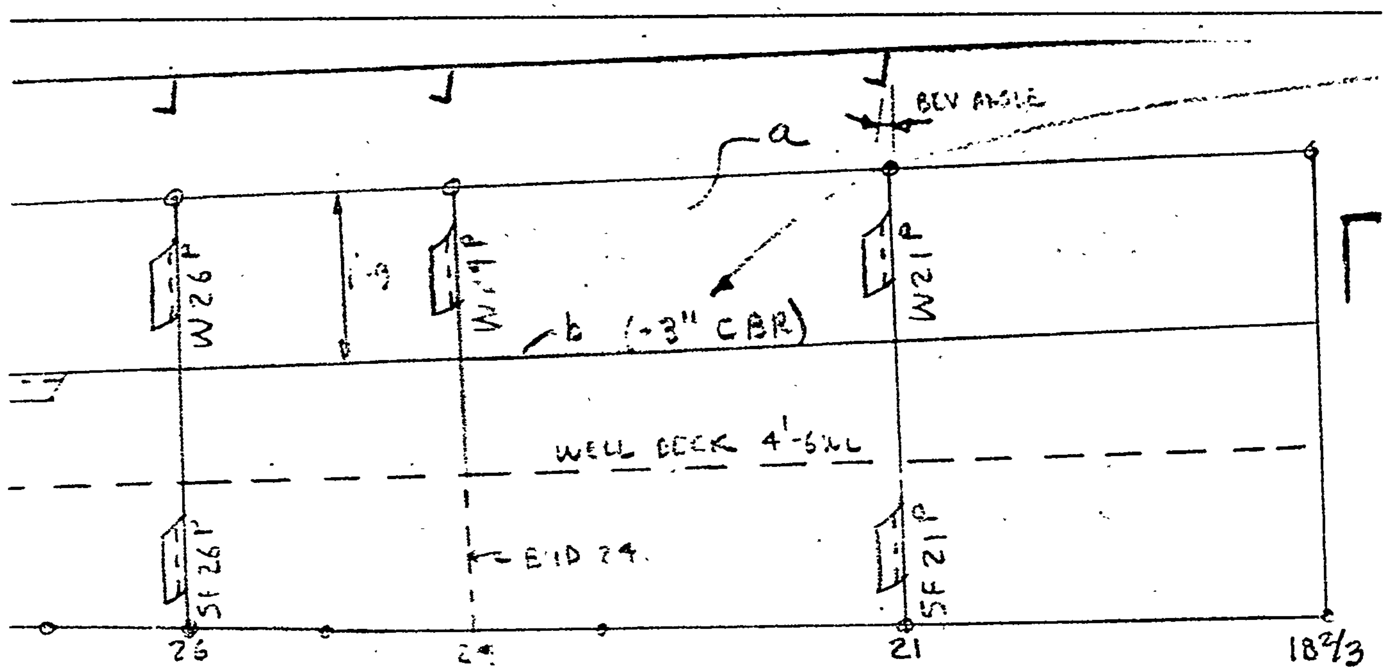


Figure 1 Typical Drawing From Naval Architect

This is a small part of a much larger drawing showing all decks on an Offshore Supply Vessel. Although the drawing covers over 20 panels, there is not enough information to fabricate a single complete portion of the ship. Even the panel boundaries are undefined. This drawing can be greatly simplified for submittal to regulatory bodies if Steelwork Production Drawings are prepared.



ONE SIDE SHELL ASS'Y SS-1P SHOWN (LEG C.B.)
ONE SIDE SHELL ASS'Y SS-1S OPP

LOWER TRACE		BOTTOM BEVEL	TOP BEVEL	FRAME GIRTH	BILL		
X	Y				QTY	PC MARK	DESCRIP
					1P/1S	SS-1	SIDE SHELL
1-8-1	0-3-3				2	a	60"×10.2
3-3-12	0-2-8				2	b	L 3×2½×¼
6-4-0	0-1-12	FR [illegible] 5°	5°		4	c	⸗
12-9-3	0-1-3	FR [illegible] 2°	2°		1P/1S	SF21	L 6×3½
15-4-3	0-1-10	FR 24 1°	1°		1P/1S	SF26	
15-4-3	0-2-10	FR [illegible] 6°	6°		1P/1S	SF28	
21-16-3	0-7-7				1P/1S	W21	

Figure 2 Typical Steelwork Production Drawing

In contrast to the Naval Architect's drawing, this drawing shows complete information to fabricate a Side Shell Panel ready for installation on the ship with no trim required.

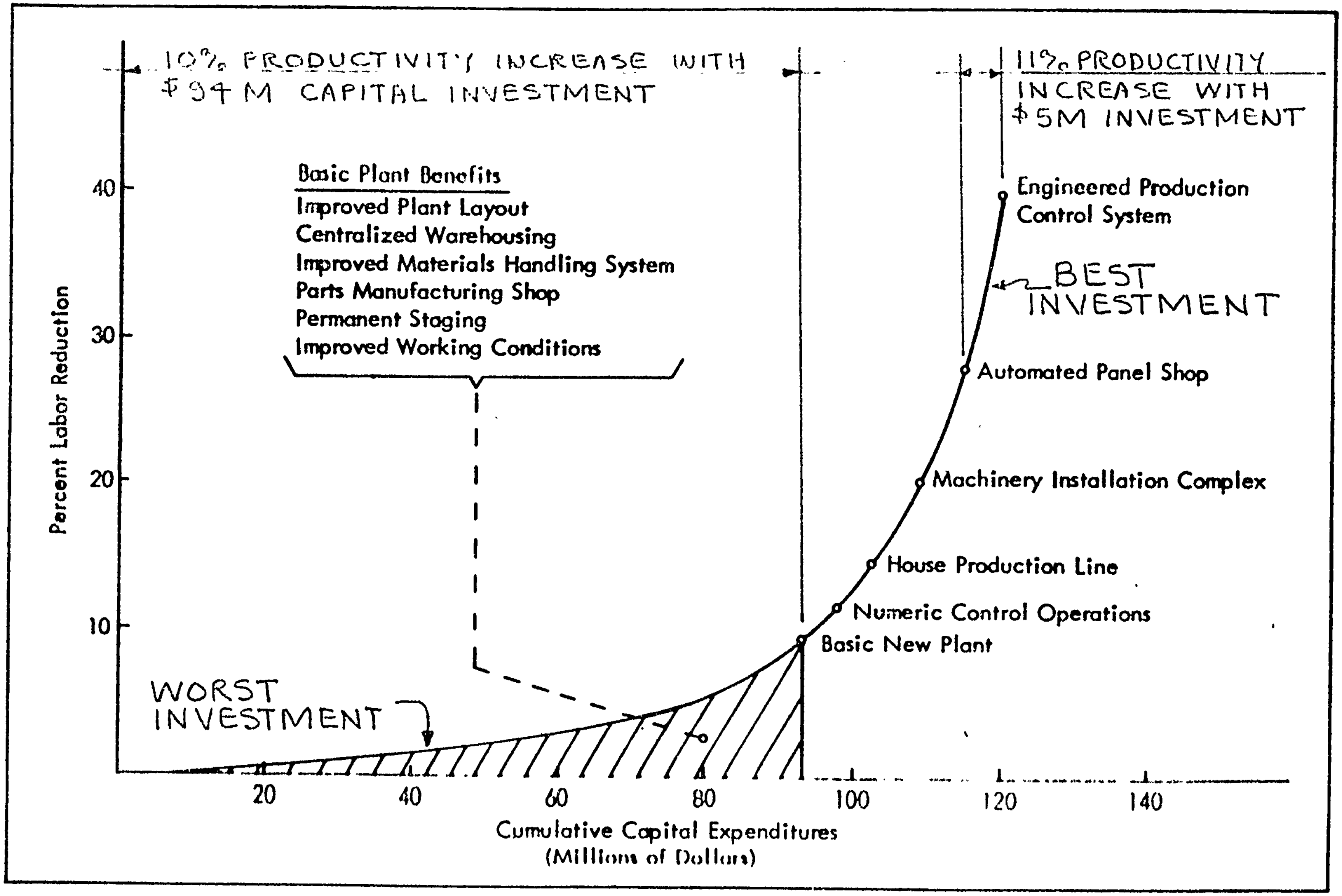


Figure 4-13 PRODUCTIVITY OF CAPITAL

Figure 3 is an excerpt from Maritime Administration CMX Project Report

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